TOPIC 3. CALCULATIONS OF FORAGE REQUIRED, ENERGY BASE

The partitioning of nutrients from gross to the metabolizable level illustrated in the first part of CHAPTER 11 makes the final expression of nutrients available compatible with the expression of metabolic requirements. It is necessary, of course, to use the same units of measurement for expressing nutrients in both the numerator and the denominator of this relationship.

Daily forage consumption in relation to energy requirements may be estimated, with both the numerator and the denominator in kcal/day, with the word formula:

forage intake in kg per day = [(ecological metabolism in kcal per day)/ (metabolically useful energy in the forage in kcal per kg)]

This word formula for predicting intake is for an animal in a neutral energy balance, with all of the energy required being met by ingested forage. This is not always the case as body reserves, especially fat, can be mobilized to supplement the ingested forage as a source of energy. The amount of forage required is then reduced.

Seasonal variations in the two components of the basic relationship--ecological metabolism and metabolic energy in the forage--occur. Absolute levels of ecological metabolism vary in relation to ages, weights and reproductive rates of deer. Seasonal variations in weights were described in CHAPTER 1, UNIT 1.4. Seasonal patterns of ecological metabolism are sinusoidal as deer go from winter minimums to summer and early fall maximums (Moen 1978) these are discussed further in CHAPTER 7, UNIT 6.1.

The breakdown of forage materials into chemical energy that can be used by an organism is not a perfectly efficient process, so the ratios of digestible energy to gross energy and metabolizable energy to digestible energy are less than 1.0. These fractions represent the portion of the food ingested that is useful to the animal at each level of breakdown; the coefficient is appropriately called the digestible energy coefficient (DECO) and metabolizable energy coefficient (MECO).

Digestibilities were discussed in CHAPTER 11, with results of in vivo, in vitro, and calculated weighted mean digestibilites given in TOPIC 3. Metabolizable energy is a fraction of the digestible energy. The metabolizable energy coefficient used for cattle and sheep is 0.82, which is multipled by digestible energy to determine the metabolizable energy in grain and roughage (NRC 1975). Wider variations in the metabolizable energy coefficient for white-tailed deer on browse diets were discussed by Robbins (1973); with metabolizable energy coefficients varying from 0.78 to 0.94 of the digestible energy. A value of 0.86 may be used as an overall estimate for deer on browse if 0.82 is not considered suitable or more specific values are not available.

Expanded formulas for calculating forage consumption, using four-letter symbols, are:

DWFK = ELMD/(GEFO)(DECO)(MECO)

DWFK = (MBLM)(70 IFMW)/(GEFO)(DECO)(MECO)

where DWFK = Dry-weight forage consumed in kg,
ELMD = Ecological metabolism per day,
GEFO = Gross energy in the forage,
DECO = Digestible energy coefficient,
MECO = Metabolizable energy coefficient,
MBLM = Multiple of base-line metabolism, and
IFMW = Ingesta-free metabolic weight.

Calculations of daily consumption based on energy balances are illustrated in the four UNITS. Seasonal variations in the dietary energy and in ecological metabolism are discussed in UNITS 3.1 and 3.2. Then, the role of seasonal variations in energy reserves are discussed in UNIT 3.3, and finally, the use of a nomogram to rapidly estimate intake is illustrated in UNIT 3.4.

LITERATURE CITED

National Research Council. 1975. Nutrient requirements of sheep. National Acad. of Sciences. Washington, D. C. 72 pp.

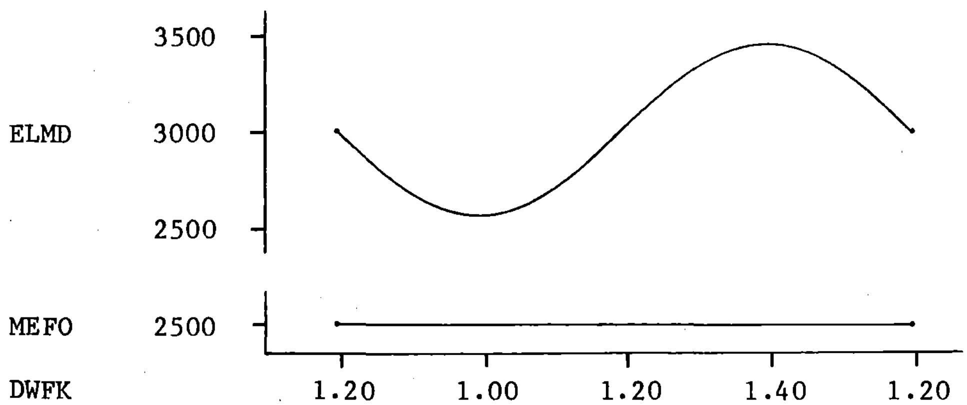
Robbins, C. T. 1973. The biological basis for the calculation of carrying capacity. Ph.D. Thesis. Cornell Univ., Ithaca, NY. 239 pp.

UNIT 3.1: EFFECTS OF VARIATIONS IN DIETARY ENERGY

Diet digestibilities and metabolic energy available in forage are dependent on current growing conditions and weather factors. Diet digestibilities usually change slowly, with a general pattern of winter minimums as animals ingest dormant forage and summer maximums as succulent new growth is ingested. Diet digestibilities may change rapidly if foraging conditions change due to an early winter snowfall, for example, which covers more-digestible herbaceous forage and fruits, leaving only woody browse exposed. Snow also makes movement to fields and other concentrated food sources more difficult for wild ruminants living in agricultural areas. Free-ranging animals consuming dormant woody browse in late winter may quickly shift to new spring growth if snow conditions permit rapid dispersal from winter concentration areas to areas with emerging spring growth.

If digestibility is related to the structure of the plant cell, then it should vary seasonally in relation to plant growth and development. The use of single average values to represent the digestibility of a forage species masks animal-range relationships that are dependent on changes in forage characteristics over time.

The effects of variations in dietary energy are illustrated with the simplified relationship below. MEFO = metabolizable energy in the forage, ELMD = ecological metabolism per day, and DWFK = dry weight forage in kg.



Calculated diet digestibilities illustrating the effects of changes in both diet compositions and in forage digestibilities over time were given in CHAPTER 11, UNIT 3.3. The effects of these changes in forage intake, given a single value for ecological metabolism, are illustrated on the WORKSHEETS.

REFERENCES, UNIT 3.1

EFFECTS OF VARIATIONS IN DIETARY ENERGY

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	39--2	321	329	odvi	nutr in diff season, south	short,hr	1975
JWMAA	42--4	776	790	odvi	diet prot, energ effc fawn	seal,us; verme,1/	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				odhe			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				ceel			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
TLPBA	14--1	105	134	alal	diet optimizatn, genl herb	belovsky,ge	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	54--5	737	751	rata	dig energy intk, gluc synt	mcewan,eh; white/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				anam			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				bibi			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				ovca			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				ovda			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				obmo			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				oram			

CHAPTER 12, WORKSHEET 3.1a

Variations in forage consumption due to differences in diet digestibilities

The formula for calculating intake is:

DWFK = ELMD/MEFO

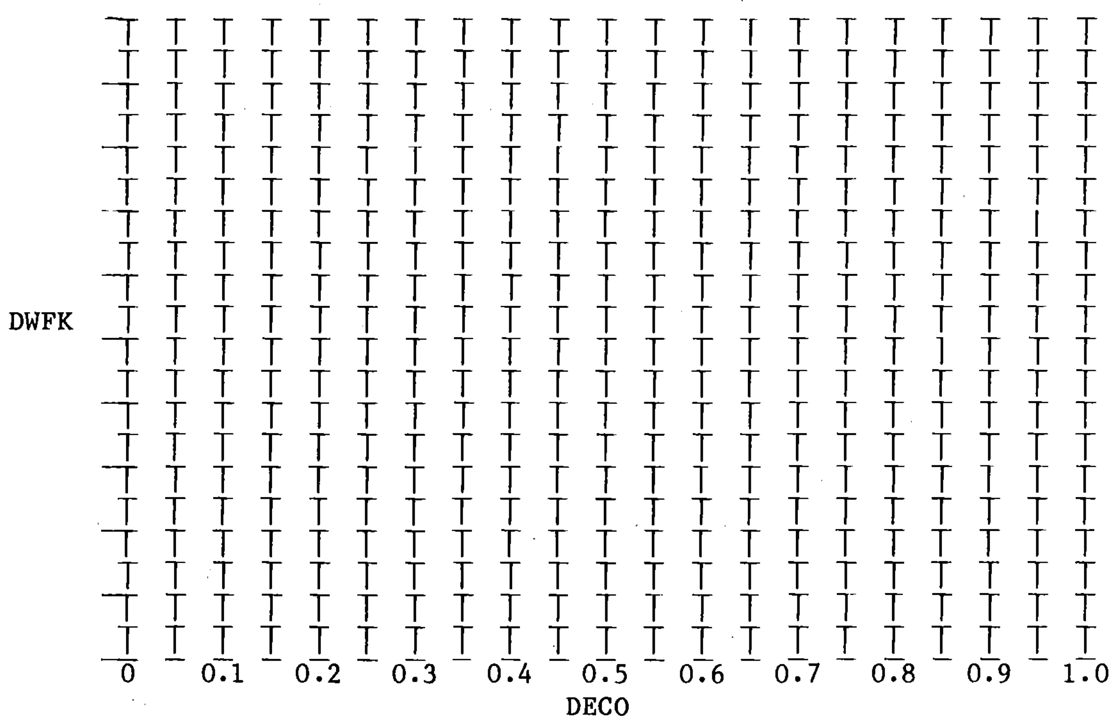
where DWFK = dry weight forage consumed in kg,
ELMD = ecological metabolism per day, and
MEFO = metabolizable energy in the forage.

Metabolizable energy in the forage is determined with the formula:

MEFO = (GEFO)(DECO)(MECO)

where GEFO = gross energy in the forage (= 4500 kcal per kg),
DECO = digestible energy coefficent, and
MECO = metabolizable energy coefficient (0.82).

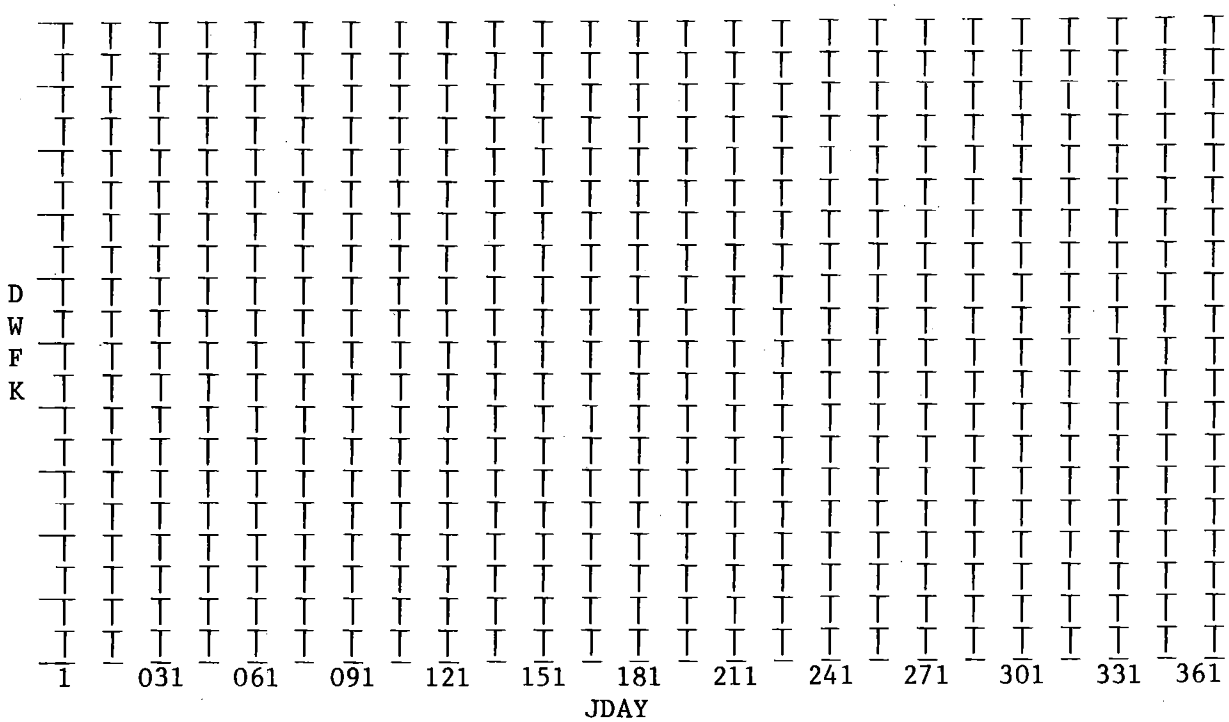
Select a value for ELMD (5000 for a 100 kg animal, for example), complete the calculation of DWFK using DECO = 0.10 to 0.90 at 0.10 intervals, and plot the results on the grid below.



CHAPTER 12, WORKSHEET 3.1b

Variations in forage consumption due to differences in diet digestibilities over time

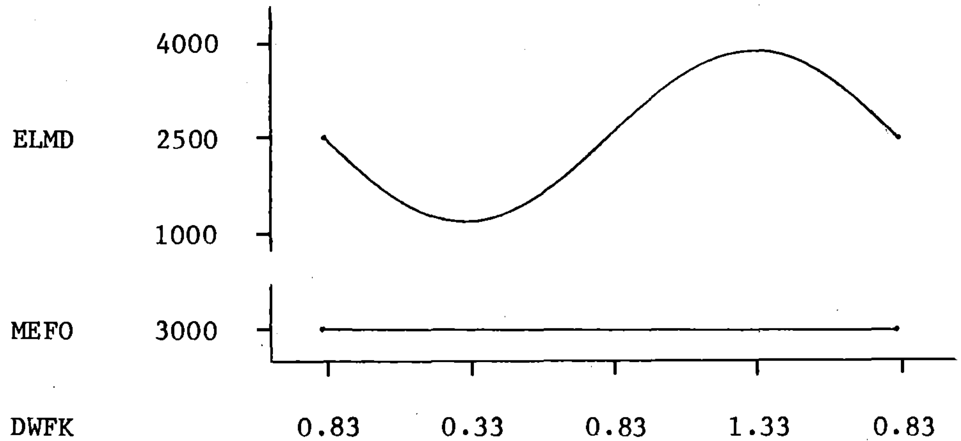
Using the same format as in WORKSHEET 3.1a, complete a new set of calculations using a variable ELMD. Start with the mean value of 5000 and incorporate a sine wave fluctuation of ± 1000 using procedures described in CHAPTER ONE, UNIT 1.4 and CHAPTER SIX, UNIT 6.1. Plot DWFK as separate lines for different DECO in relation to JDAY and ELMD.



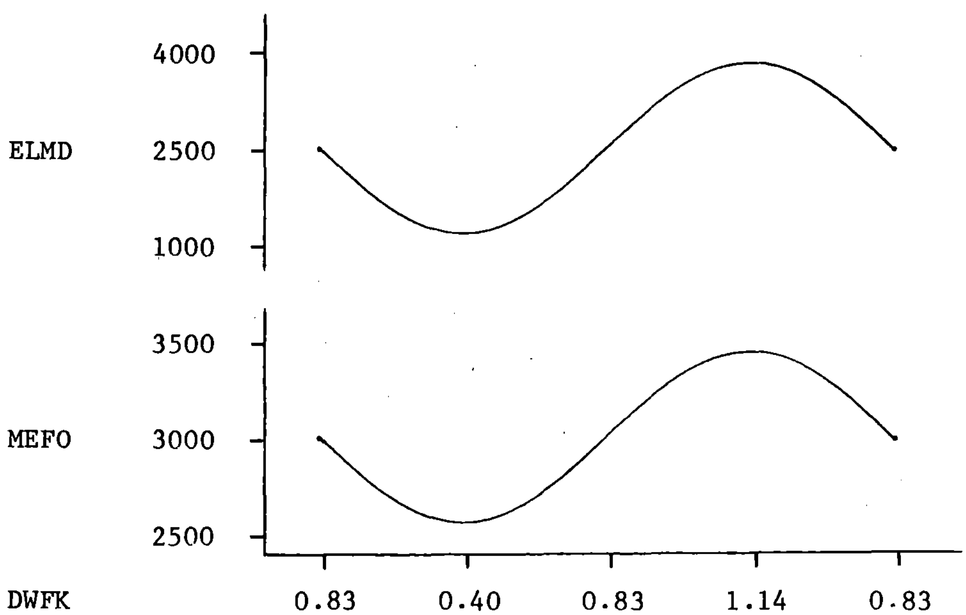
ELMD

UNIT 3.2: EFFECTS OF VARIATIONS IN ECOLOGICAL METABOLISM

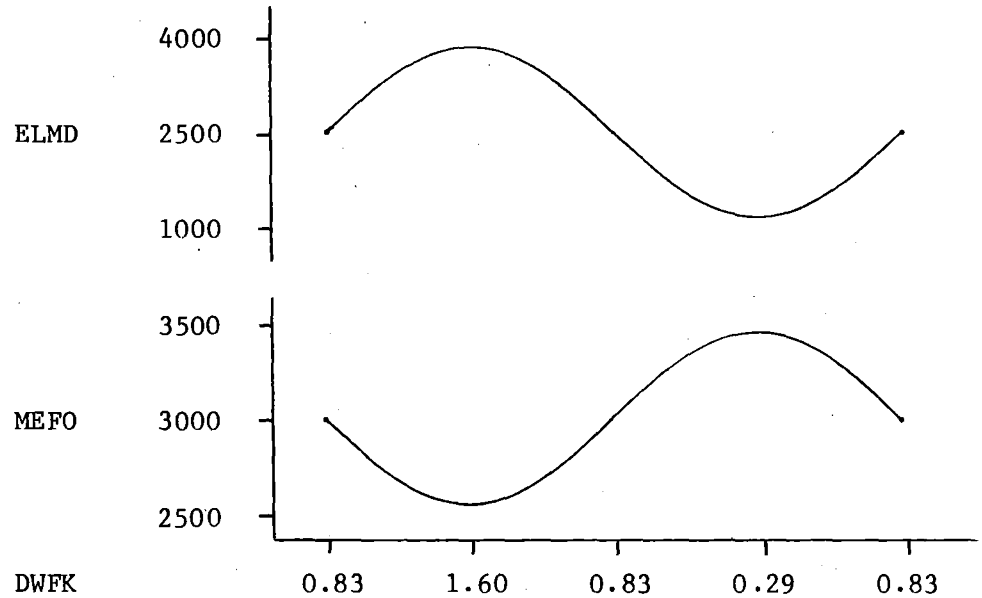
Seasonal variations in ecological metabolism, which were discussed in CHAPTER 7, UNIT 6.1, may now be used to demonstrate their effects on forage consumption. The effects are illustrated with the simplified relationship below.



Seasonal variations in ELMD and in dietary energy combine to cause seasonal variations in forage consumption. Suppose the simplified relationship above is combined with that illustrated in UNIT 3.1. Variations in DWFK as ELMD and MEFO increase and decrease in synchrony are illustrated below.



If MEFO and ELMD are not synchronized, then a marked increase in DWFK is observed when MEFO is low and ELMD is high. This would not be good adaptive strategy. In fact, high ELMD occurs when MEFO is high, early in the growing season when reproductive costs are high. Low ELMD occurs when MEFO is low; the metabolic depression at that time is good adaptive strategy.



These simplified illustrations help one understand the importance of timing and synchrony in seasonal variations of both animal and range. The ratios of change given are illustrative only as MEFO and ELMD were arbitrarily chosen. Absolute levels of ecological metabolism vary in relation to ages, weights, and reproductive rates of the animals, and variations in their activity levels through the year. Range conditions change as plants go from the dormant condition through their growth and reproductive cycles and back to dormancy again. The effects of changes in these two variables--ecological metabolism and range conditions--were discussed and illustrated for white-tailed deer in Moen (1978). Opportunities for additional calculations are provided in the WORKSHEETS that follow.

LITERATURE CITED

Moen, A. N. 1978. Seasonal changes in heart rates, activity, metabolism, and forage intake of white-tailed deer. J. Wildl. Manage. 42(4):715-738.

REFERENCES, UNIT 3.2

EFFECTS OF VARIATIONS IN ECOLOGICAL METABOLISM

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	20--3	221	232	odvi	nutr req, growth, antl dev	french,ce; mcewe/	1955
JWMAA	33--3	482	490	odvi	dig energy req does, wintr	ullrey,de; youat/	1969
JWMAA	34--3	863	869	odvi	dige, metab ener req, wint	ullrey,de; youat/	1970
JWMAA	35--1	57	62	odvi	basal diet for nutr resear	ullrey,de; johns/	1971
JWMAA	42--4	715	738	odvi	seasonal heart rates, meta	moen,an	1978
NAWTA	22---	119	132	odvi	nutrient requirements	mcewen,lc; frenc/	1957
NAWTA	34---	137	146	odvi	eff nutr, clim on sou deer	short,hl; newsom/	1969
PAABA	600--	1	50	odvi	nutr req for grwth, antler	french,ce; mcewe/	1955
TNWSD	1965.	1	13	odvi	n hamp nutr studies, aims,	silver,h; colovo/	1965

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NAWTA	22---	179	186	odhe	food requir growth & maint	cowan,imct; wood/	1957

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				ceel			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
TLPBA	14--1	105	134	alal	diet optimizatn, genl herb	belovsky,ge	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CBPAB	60A-2	123	126	rata	seas chng grwth horm, norw	ringberg,t; jaco/	1978
SZSLA	21---	117	128	rata	aspcts of nutr, semi-domes	steen,e	1968

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

anam

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

bibi

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

ovca

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

ovda

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

obmo

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

oram

UNIT 3.3: EFFECTS OF SEASONAL VARIATIONS IN ENERGY RESERVES

Seasonal weight patterns of wild ruminants are more than interesting anatomical features--they are reflections of storage and mobilization of metabolic reserves, primarily fat, in relation to seasonal variations in range productivity. Increases in the cost of living--ecological metabolism--are observed in late summer and early fall as fat reserves accumulate. As ecological metabolism decreases in the winter, the fat reserve is a source of energy that ameliorates the need for ingesting all of the energy needed. The formula for determining forage consumption when energy reserves are mobilized to supplement the ingested forage as a source of energy is:

forage intake in kg per day = [(ecological metabolism in kcal per day) - (energy metabolized from energy reserves)]/(metabolically useful energy in the forage in kcal per kg)

The contribution of mobilized body tissue to the metabolic energy and the forage equivalent it replaces can be determined by first calculating the weight loss per day using procedures described in CHAPTER 1, UNIT 1.4. Then, determine the composition of the body at the weights calculated (See CHAPTER 2, UNIT 2.1) and the change in fat mass concomitant with the weight loss. Multiply the mass of the fat mobilized by the caloric content of fat (See CHAPTER 7, UNIT 3.1) to get the calories of energy available due to the weight loss and fat depletion. Subtract that quantity in kcal from ELMD. If protein is contributing kcal to the metabolic requirement, multiply the mass of protein mobilized by the caloric content of protein and subtract that quantity in kcal from ELMD also.

After the quantity of kcal that is made available by mobilizing energy reserves has been calculated, it can be expressed as a forage equivalent by dividing the kcal mobilized from energy reserves by the metabolizable energy in the forage. The formula is:

FOEQ = KMER/MEFO

where FOEQ = forage equivalent,
KMER = kcal mobilized from energy reserves, and
MEFO = metabolizable energy in the forage.

This calculation helps one realize the contribution of the fat reserves to the reduction in forage required through the weight-loss period.

Calculations of the contributions of the fat reserves to the energy metabolized and forage required are made in WORKSHEETS.

REFERENCES, UNIT 3.3

EFFECTS OF SEASONAL VARIATIONS IN ENERGY RESERVES

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	9---4	319	322	odvi	symptoms malnutrition, dee	harris,d	1945

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	65--2	68	79	odhe	die comp, ener resrv, preg	holl,sa; salwass/	1979
PMASA	19---	72	79	odhe	annua cycl of condtn, mont	taber,rd; white,/	1959

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				ceel			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
TLPBA	14--1	105	134	alal	diet optimizatn, genl herb	belovsky,ge	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				rata			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				anam			

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

bibi

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

ovca

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

ovda

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

obmo

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

oram

CHAPTER 12, WORKSHEET 3.3a

Calculations of the effect of a constant weight loss on fat reserves and energy mobilized on forage required

The contribution of mobilized fat to energy metabolism may be calculated with the following formula, which is a symbol form of the word formula on page 41:

$$DWFK = (ELMD - KMER)/MEFO$$

The contribution of the fat reserve is subtracted from the daily ecological metabolism, resulting in the amount of metabolism left to be supported by forage.

The following steps will illustrate how calculations are made.

1. Calculate ELMD as a function of weight. Begin with an ingesta-free weight of 100 kg and a constant MBLM of 2.5 in this sample calculation. Thus:

$$ELMD = (2.5)(70)(IFWK^{0.75})$$

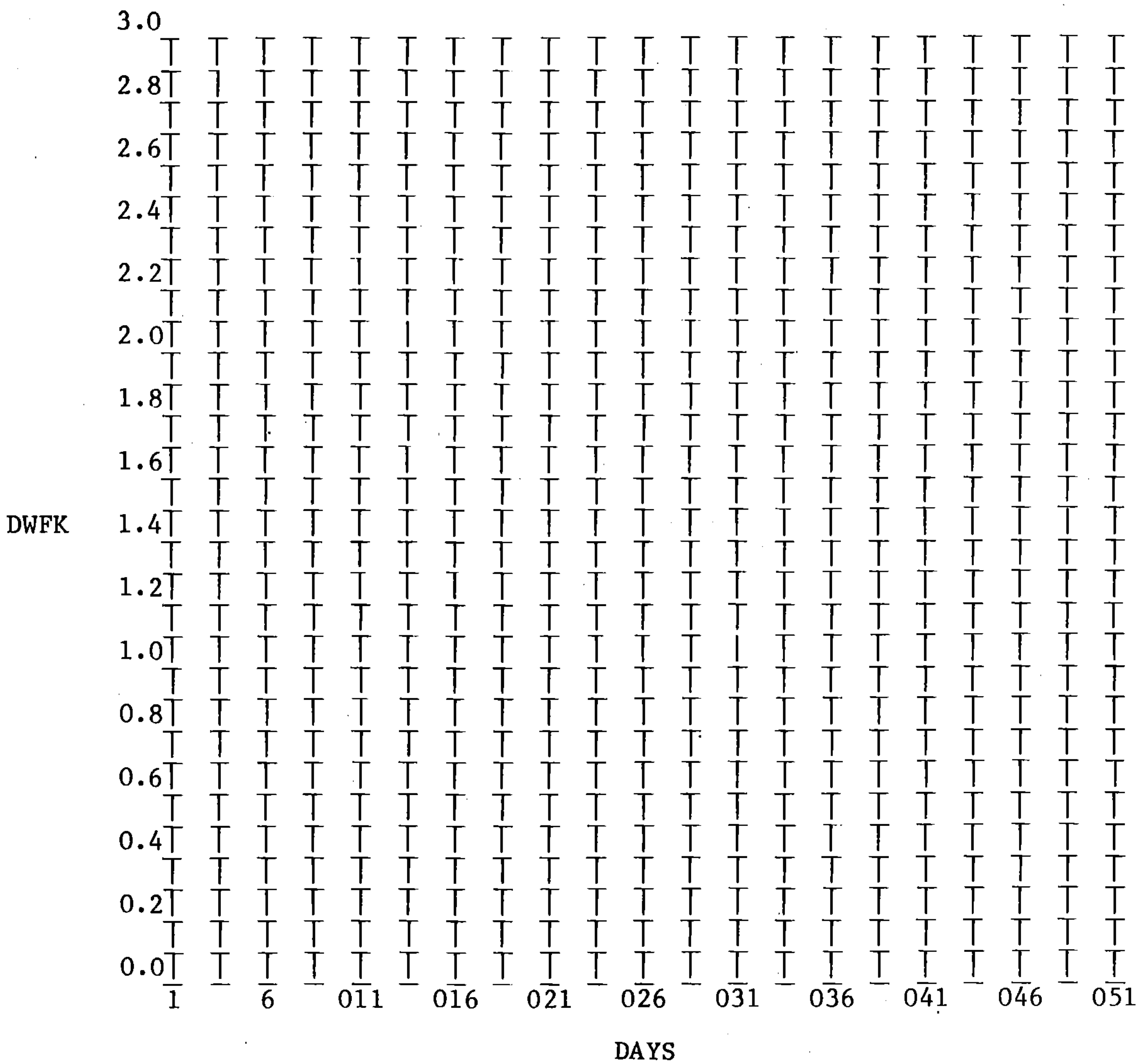
2. Suppose 0.25 kg of fat is mobilized each day. At 9500 kcal per kg:

$$KMER = (0.25)(9500) = 2375$$

3. Suppose the metabolizable energy in the forage is 0.82 of the digestible energy and DECO = 0.50. Then:

$$MEFO = (4500)(0.50)(0.82) = 1845$$

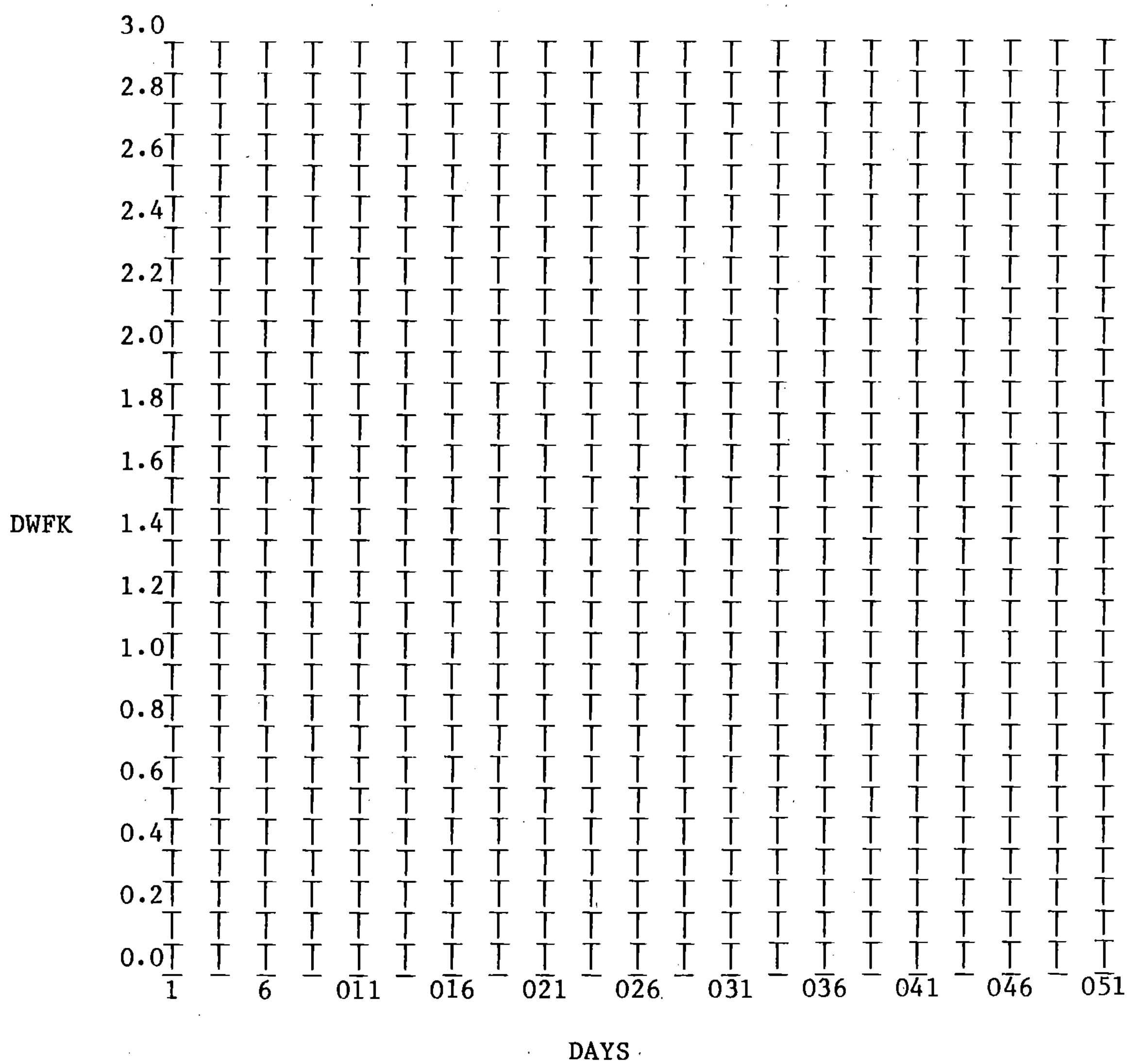
Substitute the values derived in Steps 1-3 in the formula above and determine DWFK. Then, repeat the calculations, but remember to use a new IFWK because 100 - 0.25 = 99.75. This results in a new ELMD. Repeat this adjustment each time. Plot the results in the grid on the next page. I suggest you use 5-day intervals, resulting in a weight loss of 5 x 0.25 = 1.25 between calculations.


3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
DWFK
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1
6
011
016
021
026
031
036
041
046
051
DAYS

CHAPTER 12 - WORKSHEET 3.3b

Calculations of the effect of a percent weight loss on fat reserves and energy mobilized on forage required

This WORKSHEET is like the previous one except that weight loss is calculated as a percent of IFWK rather than a constant 0.25 kg per day. Consider weight loss to be 0.25% of IFWK, or (0.0025)(IFWK). Cycle through the calculations as in WORKSHEET 3.3a, and plot the results below.



CHAPTER 12 - WORKSHEET 3.3c

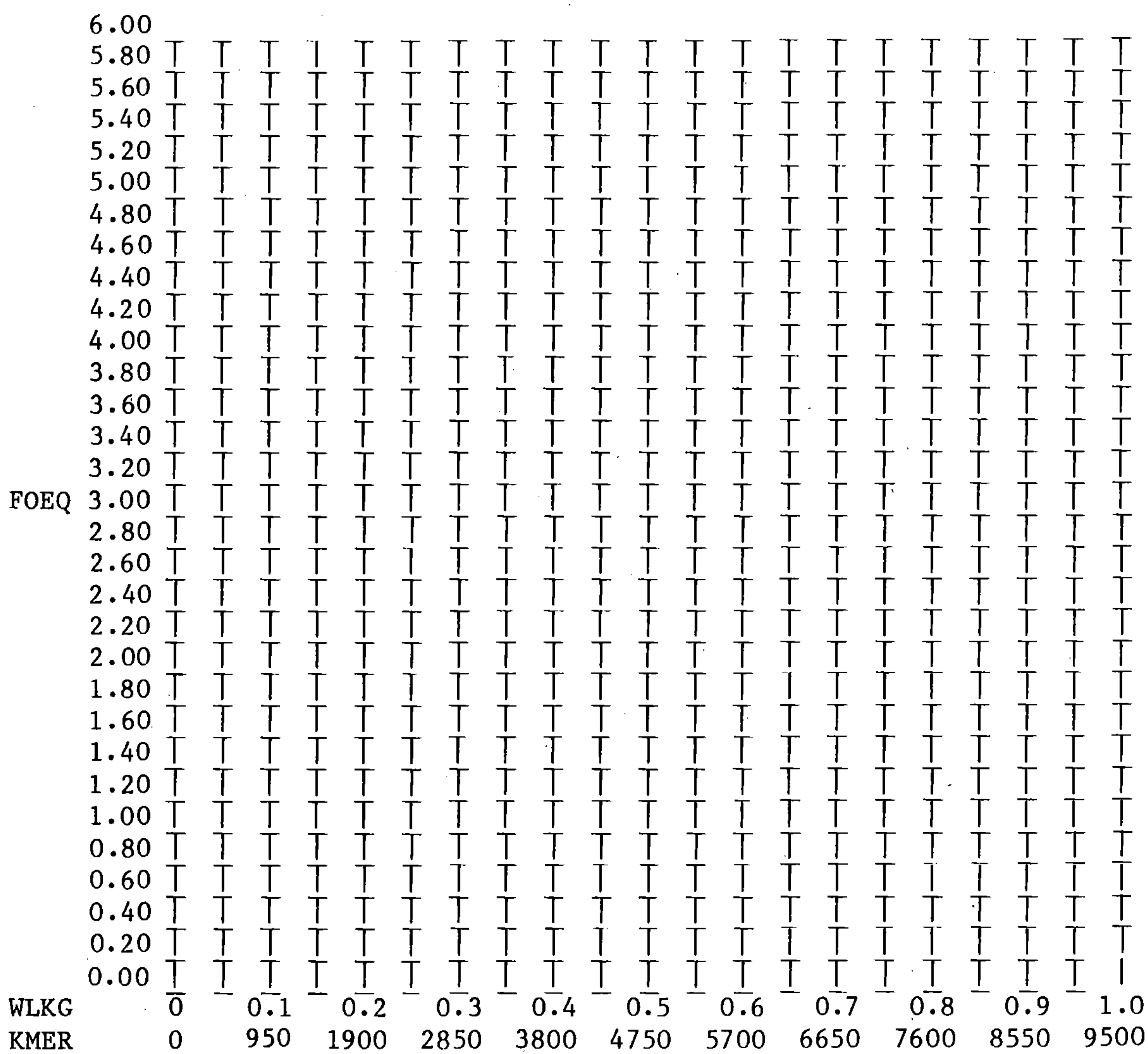
Forage equivalents of mobilized fat reserves

The amount of forage replaced by fat mobilized as a source of energy for metabolism may be calculated with the formula:

FOEQ = KMER/MEFO

where FOEQ = forage equivalent (in kg),
KMER = kcal mobilized from energy reserves, and
MEFO = metabolizable energy in the forage.

A nomogram may be plotted by considering weight loss in kg (WLKG) and KMER on the x-axis, FOEQ on the y-axis, and MEFO as a family of curves identified by DECO. Substitute the numerical values into the formula, calculate FOEQ, and plot the results to make the nomogram. The line for DECO = 0.50 is already plotted.

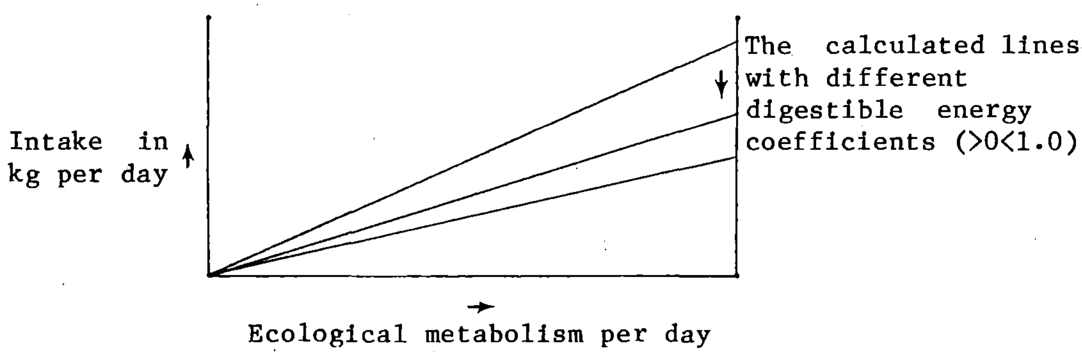


UNIT 3.4: NOMOGRAPHIC PREDICTIONS OF FORAGE REQUIRED, ENERGY BASE

Forage requirements can be predicted from two biological functions--ecological metabolism of the animal and metabolic energy in the forage. The variations in each of these through the year make the calculations tedious when done manually. Programmed computing is very useful when available. A quick way to estimate forage required is by the use of a nomogram.

Estimates of forage requirements made with a nomogram are less accurate than those calculated with programmed computing, but they may be quickly made and are likely to be as accurate as estimates of the number of animals in a population. Further, nomogram estimates are easy to make as seasonal variations in metabolism and diet digestibilities occur.

Nomograms for estimating forage requirements have been published in Moen and Scholtz (1981) and Moen (In Press). The nomograms include ecological metabolism per day on the x-axis, a family of curves for different digestible energy coefficients, and predicted forage requirements on the y-axis. These are illustrated below.



The formulas for calculating the values to be plotted as the DECO lines were given in TOPIC 3 of this CHAPTER (Pages 33-34). In symbol form, the formula is:

$$DWFK = ELMD/(GEFO)(DECO)(MECO)$$

where DWFK = dry-weight forage consumed in kg,
ELMD = ecological metabolism per day,
GEFO = gross energy in the forage,
DECO = digestible energy coefficient, and
MECO = metabolizable energy coefficient.

Be sure to consider the metabolizable energy coefficient when calculating the metabolizable energy in the forage. Values of 0.82 to 0.86 may be used as good approximations. GEFO may be estimated to be 4500 kcal per kg. DECO varies, and is the label for each of the lines on the nomogram.

Since all the lines are straight and they intercept at zero, one needs only to calculate intake for the different digestibilities considered at the highest value of ecological metabolism and draw the lines from those points to zero. A WORKSHEET is set up to facilitate the completion of a nomogram for whatever range of values of ELMD desired.

LITERATURE CITED

Moen, A. N. [In press]. Ecological efficiencies and forage intakes of free-ranging animals. National Academy of Science Publication of a Forage Allocation Workshop, Albuquerque, N.M., November, 1980.

Moen, A. N. and S. Scholtz. 1981. Nomographic estimation of forage intake by white-tailed deer. J. Range Manage. 34(1):74-76.

REFERENCES, UNIT 3.4

NOMOGRAPHIC PREDICTIONS OF FORAGE REQUIRED, ENERGY BASE

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRMGA	34--1	74	76	odvi	nomographic est forag intk	moen,an; scholtz,	1981

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				odhe			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				ceel			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				alal			

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

rata

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

anam

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

bibi

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

ovca

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

ovda

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

obmo

CODEN)VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

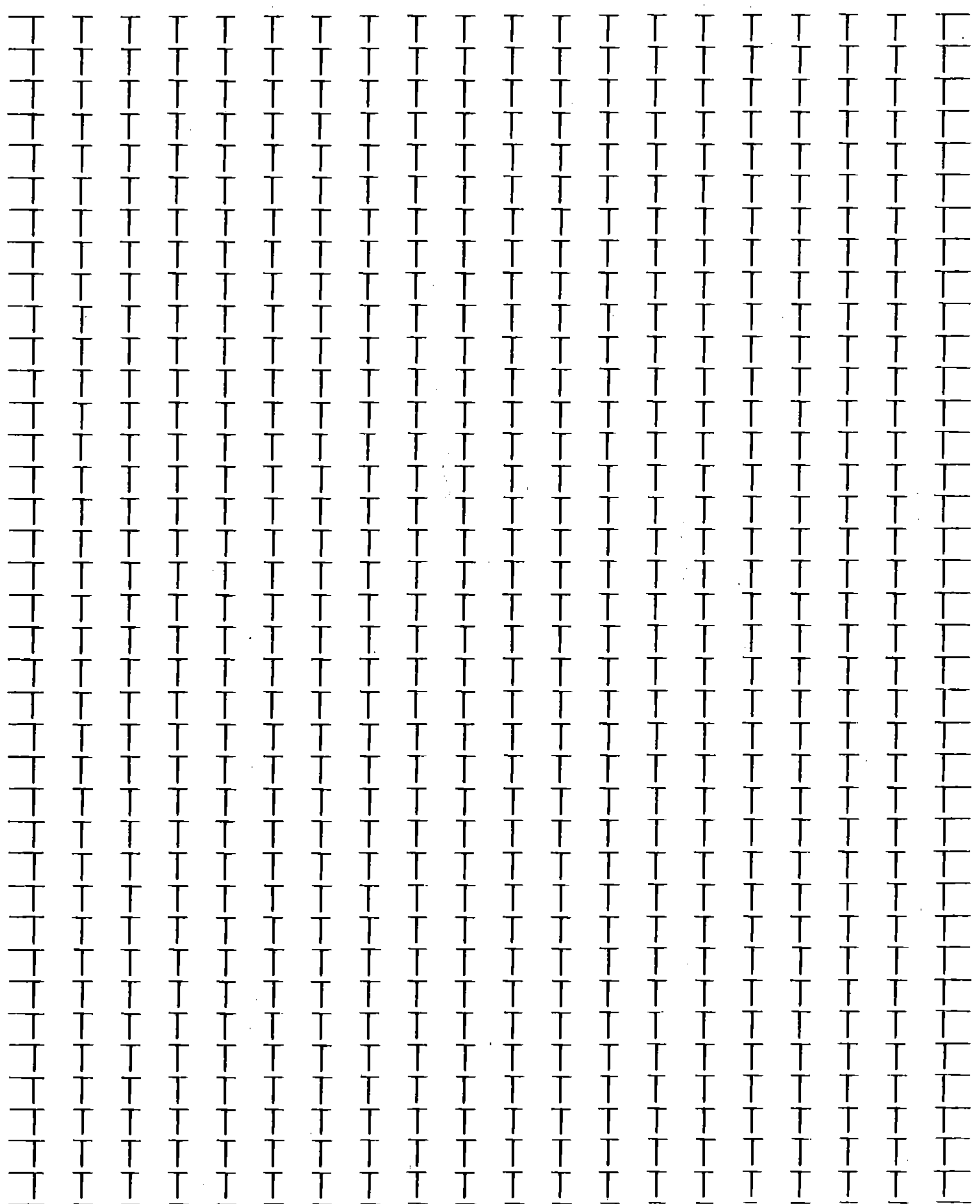
oram

CHAPTER 12, WORKSHEET 3.4a

Nomograms for making predictions of forage required, energy base

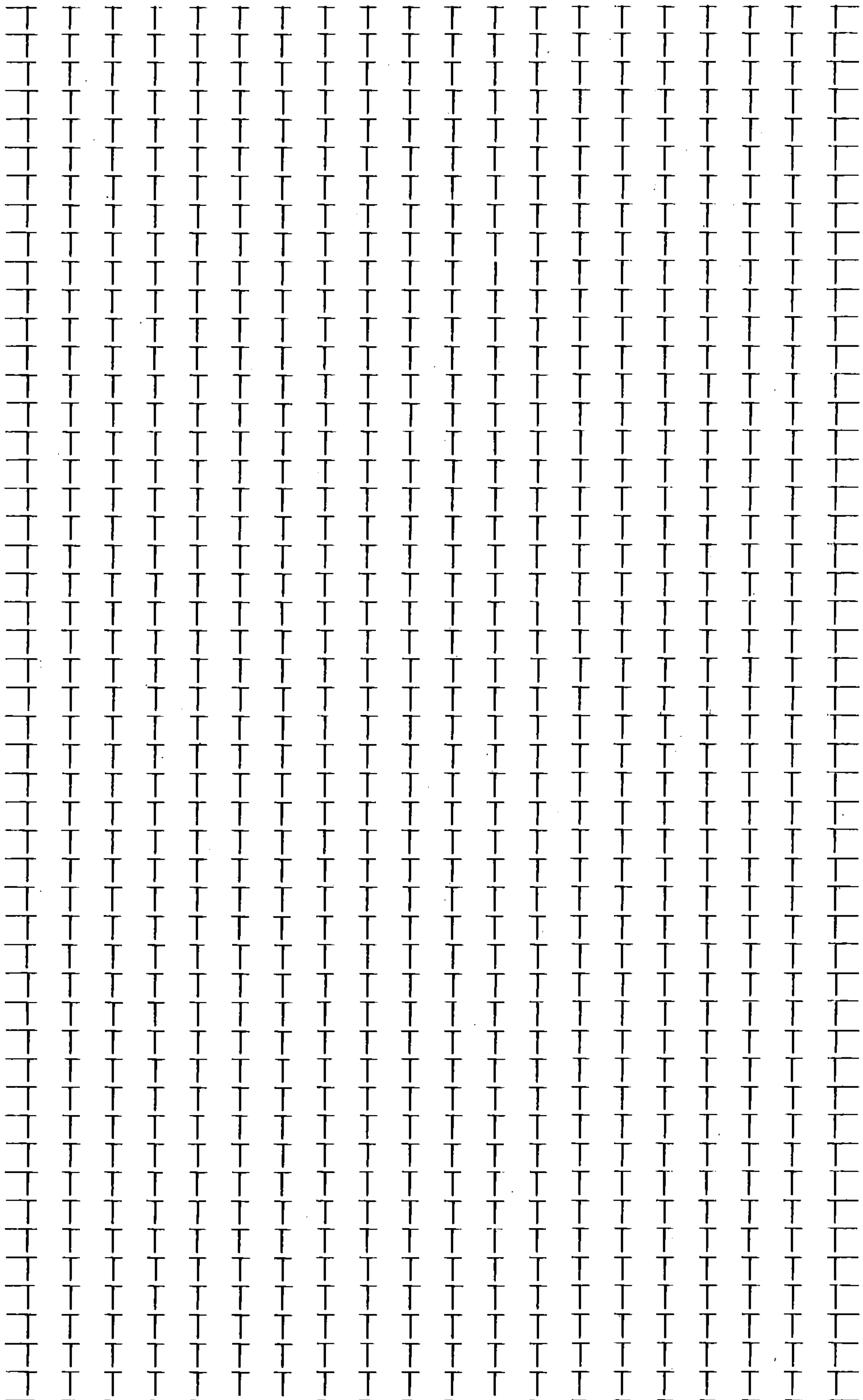
The calculations necessary for making a nomogram have been described in this UNIT (page 45) and in the publications cited. Complete a nomogram in the grid below for smaller ruminants, and in the grid on the next page for the larger ruminants. Be sure to use the metabolizable energy in the forage when making the calculations, even though the lines are labeled DECO.

DWFK



ELMD

DWFK



ELMD